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# A Comparison of Kinetic Impactor and Nuclear Deflection for Two Scenarios: Bennu and the 2015 PDC Scenario

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## ABSTRACT

Kinetic impactors and nuclear deflection are two mature technologies for mitigation of hazardous asteroids, but predicting the outcome of such impulsive deflection attempts is a challenging problem. Likely scenarios for interception and deflection typically require deflection velocities of several cm/sec, which for weakly bound chronditic objects approaches the regime of significant fracture and possible disruption. Predicting failure and fracture for well-characterized uniform materials is challenging by itself, but the varied and poorly characterized nature of asteroidal material (with wide ranges of possible composition, tensile strength, densities, and porosties) raises the difficulty that much more. Because the population of hazardous asteroids is so diverse it is important to understand the outcome of deflection techniques for representative scenarios that span this variety. This talk focuses on two such examples.

We will present models comparing kinetic impactors and deflection via nuclear standoff for two scenarios: deflecting the near Earth object Bennu (see Fig. 1 for a nuclear standoff example), and the hypothetical 2015 PDC scenario object. We select Bennu for study both because it is a large (~500 m) near Earth hazardous object, and because the upcoming NASA OSIRIS-REX mission will provide detailed data characterizing the object.

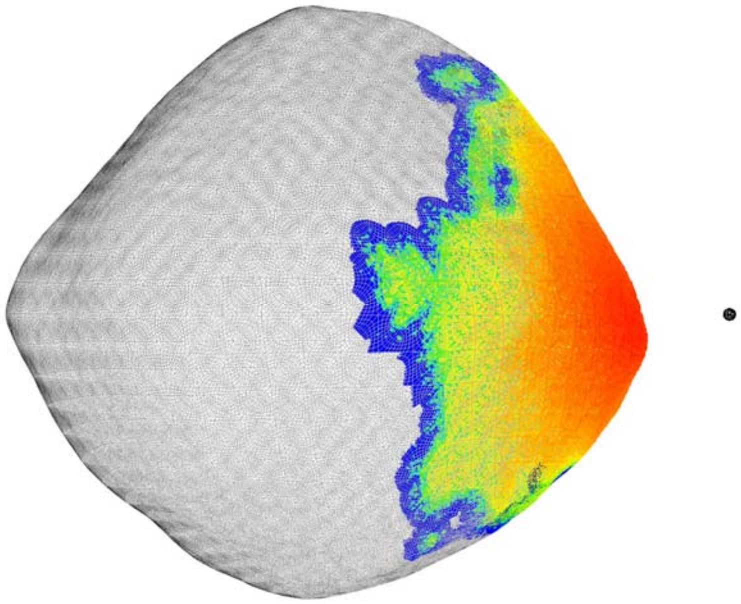

**Figure 1 -- Surface material velocity on a 3D model of Bennu (a 493 m diameter NEO) 400 μsec after exposure to a 1 Mt standoff nuclear detonation. The small sphere to the right of Bennu indicates the position of the energy source, roughly 100m above the equator. The color scale is logarithmic in velocity: blue is material moving less than 30 cm/sec, while the peak in red is expanding at 20 km/sec.**

The PDC scenario is interesting as this will be the basis of a variety of studies presented at the 2015 PDC meeting. In each case we consider the object orbits and posslble interception times in order to determine the deflection requirements. We apply our Adaptive Smoothed Particle Hydrodynamics (ASPH) [1,2] modeling methodology (employing the Spheral code [2,3]) to numerically predict the outcomes and compare with these required deflection. In the case of the nuclear deflection scenarios the anisotropic adaptivity in resolution afforded by ASPH is key in order to accurately follow the early ablation of the surface material from the asteroid, as X-ray deposition scales require resolutions at the surface of order tens of microns. We also exploit the extended damage models implemented in Spheral which have been benchmarked against a number of laboratory experiments [2] to follow the late time evolution of these scenarios, predicting the the extent of fracturing and the ultimate fate (deflection or disruption) of the objects.

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